AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 106:505–514 (1998)

Trends in Stature in the South Australian Aboriginal Murraylands

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KEY WORDS males; females; height; Roonka; Pleistocene; humans

ABSTRACT Millennial and secular changes in body height of prehistoric and recent Aboriginal South Australians are investigated. Skeletal remains of 55 male and 40 female individuals who were excavated at Roonka on the River Murray were dated from 9800 to 100 years BP. Stature was reconstructed by using humerus, femur, and tibia ratios to stature derived from Abbie's (1975) data on living Aborigines and the Trotter-Gleser method for blacks. The respective averages were 1,652 mm and 1,665 mm for males and 1,527 mm and 1,549 mm for females.

In 1996/1997, statures of 27 adult males and 21 adult females were measured in Aboriginal centers of Gerard and Raukkan (Point McLeay) on the Lower River Murray. These people, as far as it can be ascertained, are the descendants of the people from Roonka. Their statures were adjusted for the stature loss with age, so that the data represent young individuals ($\leq$30 years of age). The average male stature was 1,712 mm, and the average female stature was 1,567 mm. Data collected by Wood Jones and Campbell in 1924 for Aboriginal South Australians show that young adult male stature was 1,668 mm (n = 6), and female stature was 1,552 mm (n = 4). Slopes of regressions of individual statures on radiocarbon dates and on dates of birth are not significantly different from zero. The same is true for regressions of individual long bone lengths on radiocarbon dates. It can be concluded that there was little change in stature of Aboriginal South Australians from prehistoric to recent times. Regressions of individual age-corrected heights on birth dates (1860–1980) of Aboriginal men and women measured in 1924 and in 1996 further indicate no significant increase in height in either sex. Am J Phys Anthropol 106:505–514, 1998.

Body size of humans, similar to other mammals, is a result of long-term adaptations and short-term ontogenetic adjustments. Therefore, changes in human body size over time are a reflection of adaptations to general and particular local environmental conditions.

Hominid body size seems to have been increasing until the end of Pleistocene (Frayer, 1984; Styne and McHenry, 1993; Mathers and Henneberg, 1995). During the Holocene, human body size decreased in Europe (Frayer, 1984; Jacobs, 1985; Henneberg, 1988). It also seems to have decreased in sub-Saharan Africa (Henneberg and Steyn, 1993) and in Australia (Brown, 1992). It is unclear whether these millennial

Grant sponsor: ARC.

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Received 9 April 1997; accepted 8 April 1998.

TABLE 1. Data on Roonka individuals used in this study (Radiocarbon date is BP)

Skeleton label	Date	Sex	Age (years)	Humerus (mm)	Femur (mm)	Tibia (mm)	Ratio ht (mm)
36	7400	f	23–25		418?		1,583
110A	5000	f	30		392?		1,485
87	4400	f	35–40		418	338	1,487
35	4300	f	30		418?	353?	1,518
13w	4100	f	30–35		443	362	1,584
66	3500	f	c35		400?		1,515
54	3000	f	17–18	295?			1,553
9	2400	f	15–25			310?	1,596
33	2400	f	30		434?	376?	1,276
22	1700	f	25	316?			1,663
62	1500	f	19	278?	390?		1,470
75	1500	f?	Adult	306?	415?		1,591
32	950	f	Adult		430?		1,629
25	800	f	30–35	270?	379		1,428
7	500	f	55–60		413	356	1,515
96	350	f	c40	313	409	353	1,550
14	200	f	25–30		442	373	1,643
78	200	f	25–30	322	444	377	1,605
38	170	f	45		402?		1,523
28	na	f	20–25		422	344	1,507
30a	na	f	16–17		382?	378?	1,501
31	na	f	23	323	448?	368	1,637
32A	na	f	35		404?	349	1,483
43	na	f	35	282	372		1,447
55	na	f	24	309	422	363	1,573
62A	na	f	18	266?	357?	313?	1,347
82	na	f	35–40	291	399?		1,521
B2	na	f	na		428?		1,621
B3	na	f	35–40		406		1,538
B5	na	f	25		432	368?	1,575
B7	na	f	25–30		400?		1,515
RG B sk3	na	f	30	280?		332?	1,420
RG B sk6	na	f	40–45		398?		1,508
A 57640	na	f	na		412?		1,561
A 57641	na	f	Adult	307?	420?		1,603
A 57642	na	f	Adult	293		322	1,434
A 57687	na	f	23–25		450	383	1,640
Salt ck. sk3	na	f	55–60		420?	362?	1,540
Salt ck. sk1	na	f	35		402?		1,523
0A1 sk2	na	f	30–35		375	320?	1,369
37	9800	m	40		441?		1,664
89	7000	m	c30	322	472?	370?	1,668
106	7000	m	18–19	317?	437?		1,659
63	6600	m	45		440?		1,660
107	5900	m	45		430?	348?	1,530
12a	4800	m	55	305	420?	355	1,552
16a	4400	m	30		465		1,755
1	4300	m	c22	371?	492?		1,905
23	4200	m	>45	330	530	400	1,653
91	4200	m	40–45	328?	444?	377?	1,797
12ay	4100	m	18		482	410?	1,757
45	3800	m	25	320?	460?	402	1,694
109	3800	m	30		434?		1,638
51	3700	m	50		432?	360?	1,559
11a	3300	m	30–35	340?			1,790
90	2900	m	c45	322?	443?		1,683
108	2900	m	25–30		438?	362?	1,574
5a	2800	m	50–55		496?		1,646
92	2800	m	50	324?	444	377	1,872
21a	2500	m	25–35			362?	1,786
21A	2500	m	17	318?			1,674
50	2500	m	50	341	471		1,496
21By	2400	m	25–30		446?	382	1,631
61	1650	m	60	330?	452?		1,721
10a	1600	m	30		450?		1,698
40 and 40A	1100	m?	na			360?	1,488
65	700	m	c20	310	441	364	1,600
17	600	m	20	328?			1,726

TABLE 1. (continued)

Skeleton label	Date	Sex	Age (years)	Humerus (mm)	Femur (mm)	Tibia (mm)	Ratio ht (mm)
34	500	m	25		425	336	1,626
80	500	m	c40	316	441	375	1,496
30	250	m	30		463.5	396	1,693
18	200	m	30–35	322			1,695
52	170	m	40	324?			1,705
20a	100	m	30	293		354	1,502
20b	100	m	na	322?			1,663
56	100	m	30–35	315	442		1,695
15	na	m	25			357	1,475
57	na	m	40	323?			1,700
64	na	m	14/23?	279	395		1,479
83	na	m	na			370	1,529
85	na	m	35–40	316	428	375	1,609
94	na	m	45–50			382?	1,579
104	na	m?	c30	315?	468?		1,712
B1	na	m	na		430?		1,623
B4	na	m	25–30	307?	428?	352	1,562
RG 1A1 sk	na	m	45–50		443	371	1,602
RG B sk2	na	m	17–18		453?	380	1,640
RG B sk10	na	m	35		453?		1,709
RG B sk12	na	m	30–35	332			1,747
A39000	na	m	40–45	306	422	356	1,558
A42189	na	m	18		461?	390	1,676
Surface find	na	m	na			398	1,645
1A6	na	m	50–53			400?	1,653
Salt ck. sk2	na	m	55–60	380?	492?	443	1,896
A57650	na	m?	20–35		407?		1,536
Summary statistics							
Female							
Average			30.8	297	411	352	1,527
SD			9.6	19	23	22	84
n			34	15	35	21	40
Male							
Average			34.4	323	449	375	1,652
SD			11.8	19	26	22	101
n			49	29	39	30	55

changes were expressions of changing genetic adaptations or ontogenetic adjustments to changing living conditions. The majority of authors observing secular changes in body height during the last century interpret them as reflections of the quality of life. Where increases in stature occurred, they are linked to the improvement in living conditions (Roche, 1979; Prokopec, 1984; Bogin, 1988; Jamison, 1990; Malina, 1990; Sobral, 1990; Rao et al., 1993; Ulijaszek 1993; Gerver et al., 1994; Gutierrez-Muniz et al., 1994; Roberts, 1994; Spurgeon et al., 1994; Huang and Malina, 1995; Weber et al., 1995; Eiben, 1996; Hauspie et al., 1996). The lack of secular increase in stature is interpreted as an indicator of the lack of socioeconomic advancement in the same vein (Tobias, 1975, 1985, 1990; Dettwyler, 1992; Leatherman et al., 1995; Prince, 1995; Oyedeji et al., 1996). This has been suggested by observations that members of "higher classes" are taller than members of "lower classes" (Bielicki and Welon, 1982; Rosenbaum et al., 1985; Bogin, 1988).

Socioeconomic history of Australian Aborigines after the European settlement of this island continent is complex and subject to diverse interpretations. Part of the problem is due to insufficient written documentation of various events. Hence, a study of body height in a regional population as an indicator of living conditions may help to document quantitatively changes in the quality of life from precontact through the most recent times.

MATERIALS AND METHODS

Data from the skeletal sample excavated on the River Murray, about 200 km north of the mouth of the river, and from anthropometric surveys of living people in the Aborigi-

nal reserves (Gerard, located in the vicinity of Roonka, and Raukkan at the mouth of the River Murray) were used. These were supplemented by heights of living South Australian Aborigines collected early this century by Wood Jones and Campbell (1924).

Skeletal remains of 216 individuals were excavated at Roonka between 1968 and 1977 (Pretty and Kricun, 1989). At this time, one of the authors (G.L.P.) was approached by the Chairman of Gerard's Aboriginal Council and was asked to examine the skeletal biology of Roonka's prehistoric populations, so that these data could be used later as a base line for assessing the health status of the Gerard community. The people of Gerard, as far as can be ascertained, are descendants of the people of Roonka. Raukkan was chosen by the authors to be the control community, because its population consists of remnants of coastal South Australian Aborigines.

In 1974, M.P., along with D. Ellicot and K. Cotton, conducted osteological examination of the material excavated at Roonka. This included taking measurements of the maximum length of long bones. From the total of 216 individuals excavated at Roonka, we selected those that were adult, sexed, and whose remains included at least one major long bone (i.e., humerus, femur, or tibia) with a length that could be established (Table 1). The total number of individuals was 95 (55 males and 40 females). Their average ages were 34.4 years for males (sd = 11.8) and 30.8 years for females (sd = 9.6). There were 36 males and 19 females whose remains were radiocarbon dated individually.

No specific methods for reconstruction of Aboriginal stature from skeletons are available, whereas body proportions of Aborigines are reported to differ from those of other populations (see, e.g., Norgan 1994). Hence, the reconstruction of stature required careful consideration. This has been done by using for height reconstruction data on the length of humerus, femur, and tibia of living Aborigines in relation to their stature and comparing results with those obtained from the use of the Trotter and Gleser formulae (1952, 1977).

In 1975, A.A. Abbie published results of his anthropometric surveys of Aborigines in central Australia. Due to recent Aboriginal migrations and transfers, his subjects are reported to be a reasonable representation of a wider Aboriginal population. Among his data are averages of the length of humeri, femora, and tibiae and of statures of 205 adult males and 150 adult females. The author does not describe details of the measurement technique, he simply states that the classic Martin's technique was used. This technique produces on the living subjects the measurements of the length of humerus, femur, and tibia that approximate the actual length of bones. Dividing the average length of each bone by the average stature, we have found that the length of the humerus constitutes 19.0% of the stature in both males and females; the length of the male femur constitutes 26.5% of the stature, and that of female femur constitutes 26.4% of stature; male tibial length constitutes 24.2% of stature, and the female figure is 24.3%. The relative lengths of humerus and femur are similar to those obtained by skeletal measurements on other populations and recommended for the use in forensic stature reconstructions (ranges 18.8–20.3% and 26.2–27.3%, respectively; Krogman and Iscan, 1986). The tibia/stature ratio exceeds the highest values previously reported (black males, 22.6%; females, 22.2%; Krogman and Iscan, 1986). This may reflect elongation of distal limb segments in Aborigines, but it may also be a result of a discrepancy between measurement of the tibial length in a living individual and on dry bone. Stature reconstructions from bone length ratios are made simply by dividing the length of a bone by the percentage figure and multiplying it by 100. The method was used in hominid body height reconstructions, and its validity compared with regression-based methods is discussed by Feldesman et al. (1990).

Relative bone length figures obtained from Abbie's (1975) study were used to reconstruct statures of individuals from Roonka. In cases in which more than one of the three bones of an individual was measured, the stature was an average of estimates based on individual bones. These reconstructions were compared with the commonly used

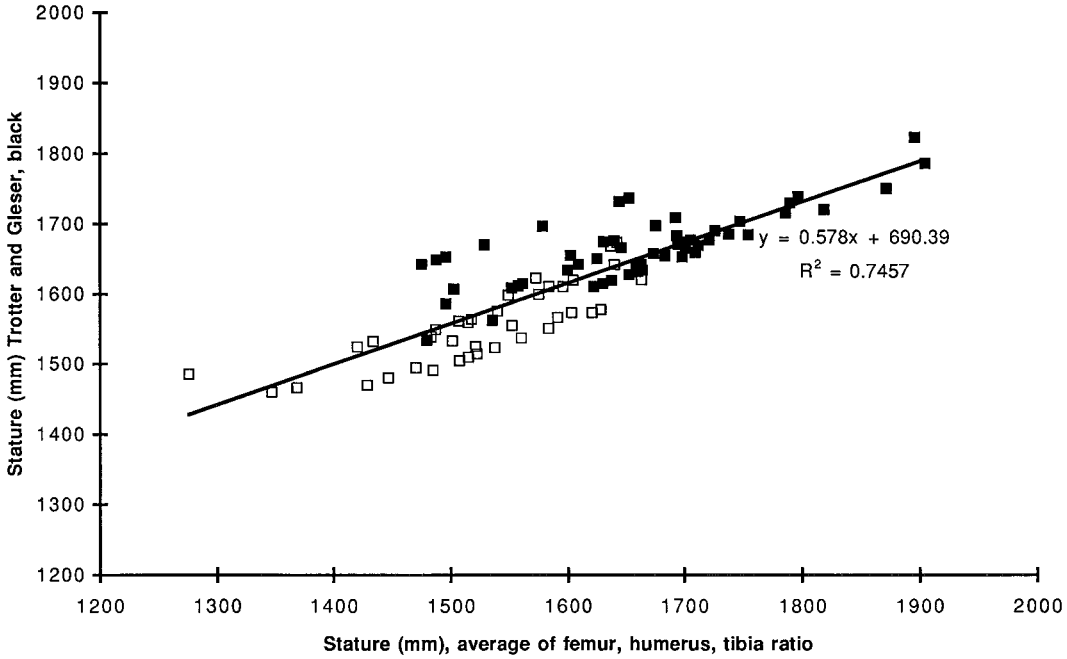

Fig. 1. Regression of stature reconstructed by means of Trotter and Gleser (1952, 1977) formulae for blacks on stature reconstructed from Aboriginal Australian long bone ratios. Roonka site (9,800–100 years BP): 55 males are represented by solid squares, and 40 females are represented by open squares. Regression line is fitted to all data points irrespective of sex estimate.

formulae of Trotter and Gleser (1952, 1977) for American blacks, whose African ancestry bears some, although remote, resemblance to climatic adaptations of native Australians (Fig. 1). The average male stature reconstructed from the long bone ratios was 1,652 mm compared with 1,665 reconstructed from Trotter and Gleser formulae for blacks, whereas the respective figures for females were 1,527 mm and 1,549 mm. Statures obtained with both methods were used in comparisons with those of living Aborigines. It is assumed here that the stature reconstructed from a long bone length reflects stature of young adult individuals in whom stature-reducing deformations of the spine and of other body parts did not occur. To our knowledge, there is no reduction of long bone length with age.

The assessment of the health status of the Gerard community began in 1996 after M.H. undertook to run this part of the project. Data from modern Aboriginal communities were collected in July 1996 and January 1997. Study samples were taken from two Aboriginal centers, Gerard and Raukkan. The centers are modern Aboriginal communities, each with a total population of approximately 120 persons (children and adults).

This study has been conducted at the written request of both communities and was approved by the University of Adelaide Human Ethics Board. Written consent of each participant has been obtained.

A standard GPM anthropometer was used to collect data following Martin's method. All measurements were taken to the nearest millimeter and are recorded and processed that way. All examinations were carried out by a team that was trained and supervised by M.H., who was present throughout the time of all examinations. All data were collected during two midday examination sessions in each community. In this way, interobserver errors were minimized. In this paper, we analyze the data on stature defined as the distance from the floor to the vertex of a bare-footed individual standing straight with the head in Frankfurt horizon-

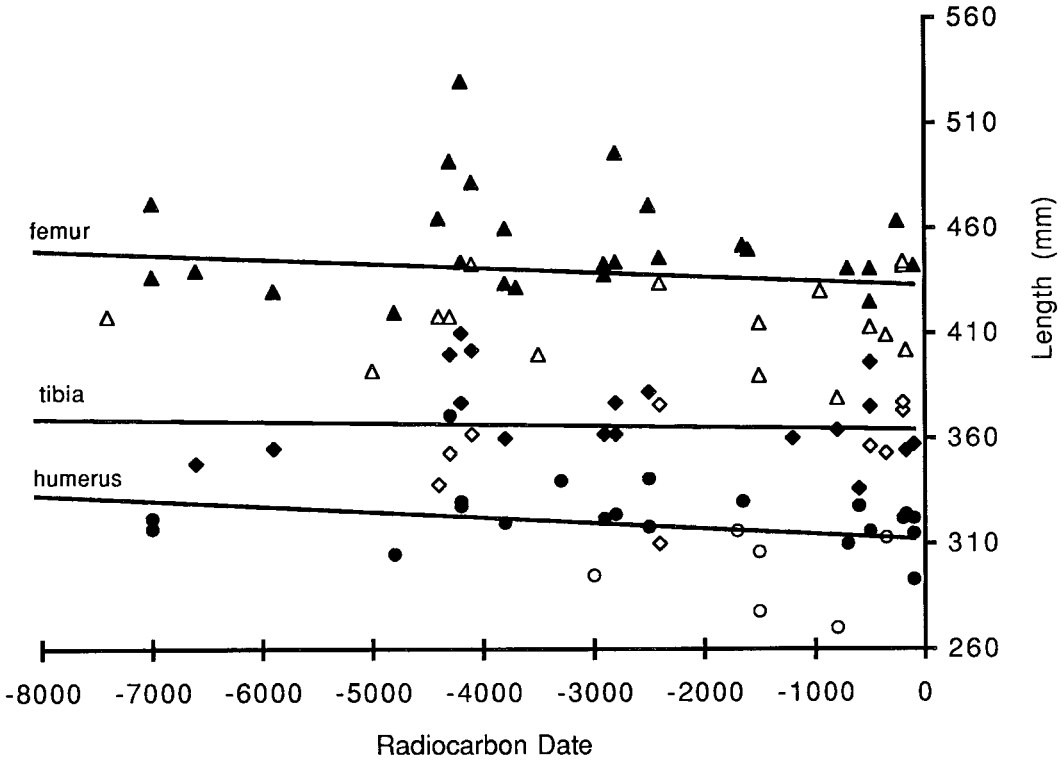

Fig. 2. Maximum length of the femur (triangles), tibia (rhomboids), and humerus (circles) of males (solid figures) and females (open figures) buried at Roonka by individual radiocarbon date. Regression lines are fitted to the data for both sexes jointly. Their slopes do not differ significantly from zero.

tal orientation. Stature measurements for both men and women 30 years of age or older were corrected for stature decline with age, according to the method of Chandler and Bock (1991). In total, 27 adult males and 21 adult females were examined from Gerard and Raukkan. The average ages were 36.1 years for males (sd = 11.2) and 33.4 years for females (sd = 10.8).

Data on body heights collected by Wood Jones and Campbell (1924) on Aborigines living in the southern part of South Australia were also included into our analyses. At the time of the execution of their study, the authors perceived that "these individuals belong to the most rapidly vanishing section of a dying race" (p. 303). Hence, although measurements of only six males and four females living in Stuart Ranges and in Streaky Bay were collected, their publication was considered to be valuable. Average male age was 45.5 years (sd = 19.0), and average female age was 32.3 years (sd = 22.4). Martin's technique was used throughout. Statures reported by Wood Jones and Campbell were age corrected in the same manner as those of the people measured at Gerard and at Raukkan. Hence, it is the statures of young adults that are compared between all of the samples studied.

The data were processed by using standard Excel 5 package. Linear regressions were calculated, and the significance of their slopes were assessed at $P = 0.05$ level. Significance of differences between arithmetic means was tested by means of unpaired t-test at the same probability level.

RESULTS

Regression of the length of humerus, femur, and tibia on radiocarbon dates (Fig. 2) indicates that there was no increase in body size within the time period represented by the Roonka burial ground. Slopes of all

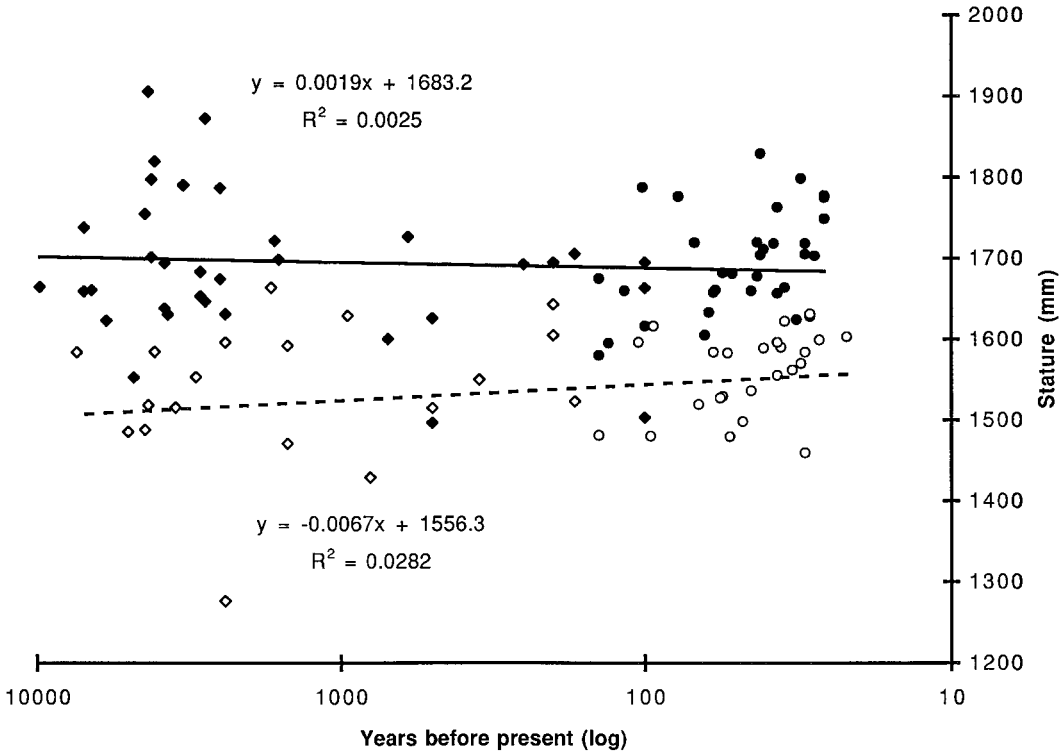

Fig. 3. Regression of statures of individuals from Roonka (rhomboids) and living South Australian Aborigines (circles) on date of birth. Solid figures; males, open figures; females. Statures of Roonka individuals are reconstructed from long bone ratios to stature, and their radiocarbon dates are taken as approximate date of birth. Due to the length of the time period covered, the date scale is logarithmic. Note that slopes of both regression lines are insignificantly different from zero.

regression lines are insignificantly different from zero. It also follows that stature reconstructed in whatever way from the length of these bones did not change.

Statures of males and females from the Roonka burial site and measured statures of living South Australian Aborigines plotted together do not indicate any substantial trends. No significant slopes of regression lines are found either when statures of Roonka people are reconstructed from long bone to stature ratios (Fig. 3) or from the Trotter and Gleser formulae for blacks (not shown). Hence, a hypothesis that there was no systematic increase of stature among South Australian Aborigines until the present day cannot be falsified.

Figure 4 shows the stature of living Aboriginal men and women of South Australia measured by Wood Jones and Campbell (1924) and by ourselves in Gerard and Raukkan communities by the year of birth. Regressions of individual age-corrected heights on birth dates for men and women indicate no significant increase in stature either in males or in females over the last 130 years. The average male stature for this entire period is 1,704 mm, and the average female stature is 1,565 mm. These averages include heights of the ten individuals who were measured by Wood Jones and Campbell in 1924. The average statures for the Wood Jones and Campbell data only are 1,668 mm for males and 1,552 mm for females (Table 2). These averages are not significantly different from the average statures for the males and females of Gerard and Raukkan measured in 1996/1997.

Averages of stature of living people from Gerard and Raukkan are significantly different from averages of some estimates for Roonka. The largest of those differences is

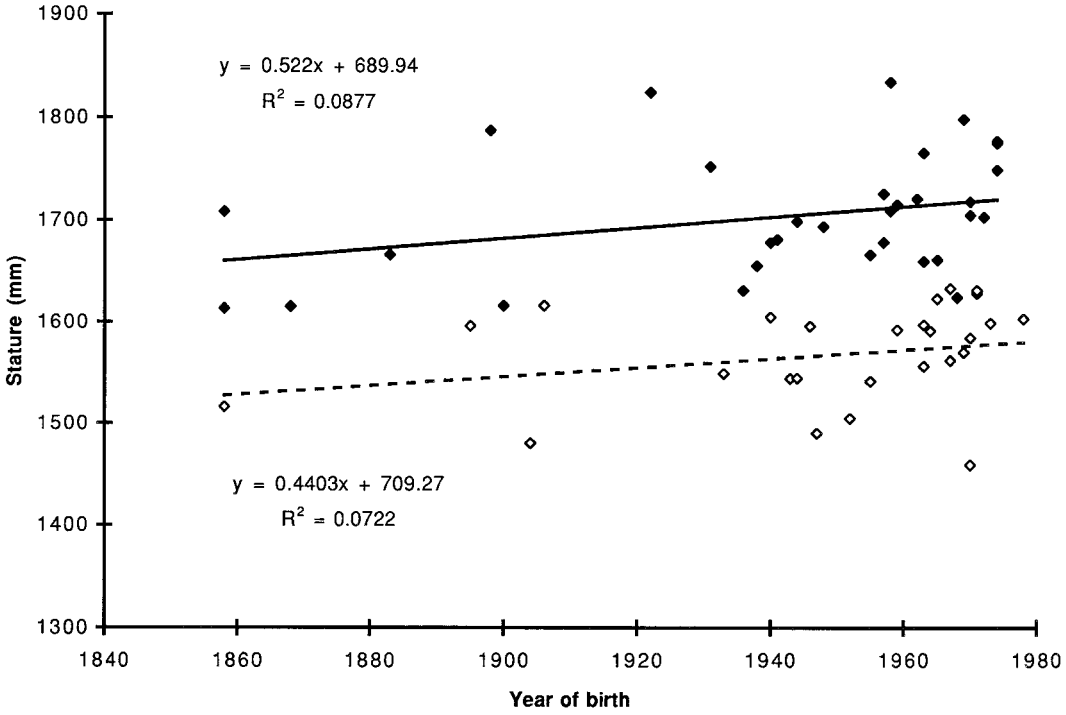

Fig. 4. Body heights of living South Australian Aborigines plotted by birth date. All heights adjusted for age to represent statures of young adults (30 years). Data were collected by the authors at Gerard and Raukkan and by Wood Jones and Campbell (1924). Solid rhomboids, males; open rhomboids; females. Slopes of regression lines are insignificantly different from zero.

TABLE 2. Average body heights of South Australian Aborigines (mm)[1]

Source	Males			Females		
	n	x	sd	n	x	sd
Roonka (T and G black, dated)[2]	36	1,666	44	19	1,556	51
Roonka (T and G black, all)[2]	55	1,665	52	40	1,549	50
Roonka (ratios, dated)	36	1,665	100	19	1,537	89
Roonka (ratios, all)	55	1,652	101	40	1,527	84
Stuart Ranges and Streaky Bay[3]	6	1,668	70	4	1,552	65
Gerard and Raukkan	27	1,712	57	21	1,567	44

[1] All individual heights of living people were adjusted to represent statures of young adults. x, arithmetic mean.
[2] T and G, Trotter and Gleser (1952, 1977).
[3] Data from Wood Jones and Campbell (1924).

60 mm. Considering large confidence intervals for each average, possible systematic errors in stature reconstructions, and the fact that such difference would have to occur over at least several hundred years, this observation does not indicate a substantial increase in stature over the time period studied.

DISCUSSION

Although the sample sizes used in the present study were too small to capture slight fluctuations in body size, it is apparent that no major changes in stature occurred during the Holocene and that no clear-cut secular trend has been present in the 20th century. If a trend of the magnitude of that observed in Europe (100–150 mm; Wolański, 1978; Van Wieringen, 1986; Henneberg and van den Berg, 1990) had been present, it would have been visible in our data sets, producing significant differences despite small sample sizes. The following calculation supports this latter statement. If

one takes average male stature, as observed by Wood Jones and Campbell in 1924, i.e., 1,668 mm (n = 6; sd = 70 mm) and increases it at 10 mm per decade until 1996, then the final stature of males should be 1,740 mm. With the actual male sample size and standard deviation, as measured by ourselves in 1996/1997, i.e. n = 27 and sd = 57 mm, the theoretical 1996 stature of 1,740 mm would be significantly different from the 1924 average at 0.05 level ($t^0 = 2.607$). The slope of the regression line equaling 1.00 would also be significantly different from zero with a sample size of 33.

The lack of secular trend among Aboriginal males studied here parallels that observed among South African blacks (2.4 mm/decade; Henneberg and van den Berg, 1990), who were hampered in their socioeconomic advancement by the policies of apartheid. Our findings do not corroborate earlier observations that indicated a significant positive secular trend in stature of Aborigines in the Northern Territory (Barret and Brown, 1971). Such findings may be a result of quite different situation of people in the Northern Territory, but, likewise, they may be a result of reporting of isolated facts that fit a well-established paradigm of general increase in stature.

The problem of comparability of stature reconstructed from skeletal remains with that measured on living individuals has no perfect resolution, because, theoretically, each human population may have somewhat different body proportions; thus, stature reconstruction equations that are developed on a sample from one particular population are valid for that population only. It seems, however, that the lack of a trend in the length of particular bones at Roonka and the lack of a significant trend in statures of living people born over the last 130 years strongly suggest the absence of clear-cut body size change in Southern Australia.

Our results must be treated as preliminary, because collection of larger data sets is required before firm conclusions can be reached. However, we feel justified already at this stage to say that the lack of substantial increase of stature of South Australian Aborigines is coupled with their much higher mortality (Kirke et al., 1993), indicating that Aborigines may not have benefited from the overall improvement in living conditions and health care that has occurred in Australia throughout the 20th century.

ACKNOWLEDGMENTS

This study was partly funded by an ARC grant for "Ongoing Human Evolution."

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